Research Needs in Fire Safety for the Human Exploration and Utilization of Space

A Workshop Sponsored by:

NASA Office of Biological and Physical Research

Hosted by:

NASA Glenn Research Center

and the

National Center for Microgravity Research on Fluids and Combustion

June 25-26, 2001
Sheraton Airport Hotel
Cleveland, Ohio

Objective

The objective of this workshop is to bring together experts in various disciplines related to spacecraft fire safety to (1) identify research needed to ensure fire safety in future Shuttle and International Space Station (ISS) systems and payloads, (2) promote ISS fire safety through proposals for innovative designs, operations, and validation procedures, (3) identify areas of concern related to fire safety inherent to long-duration space missions in Earth orbit and beyond, and (4) anticipate research required to plan and design habitats for planetary exploration. The outcome of this workshop will be a prioritized list of immediate and long-term areas of concern and the research studies and design improvements necessary to alleviate those concerns from which a formal fire safety research plan can be developed.

Background

Space travel is inherently dangerous so safety is of primary concern in the space program. The vehicle structure and the crew are exposed to high levels of stress, and the hostile external environment makes escape and rescue nearly impossible. Many potential hazards can arise in space operations, among which are fire, atmospheric contamination, injury, explosion, loss of pressure, and meteoroid and debris penetration. These are examples of prompt-effect hazards, that is, those requiring immediate response for alleviation. Space operations are also subject to delayed-effect hazards, which are those requiring less urgent or timely response, such as contamination, hidden damage, and corrosion. Fire is a foremost and greatly feared prompt-effect hazard, but it also contributes to the delayed-effect hazards. Hence, fire-protection strategies must cover the restoration, repair, and cleanup activities after a fire event in addition to the obvious prevention and control before and during a fire.

Probably the most important factor distinguishing spacecraft fire protection from terrestrial procedures in extreme environments (*e.g.*, submarines and aircraft) is the strong influence of the low-gravity environment that dominates fire and particulate behavior and control in spacecraft. The substantial upward buoyant flow generated by large density gradients in fires at 1-g is practically eliminated in spacecraft. Heat and mass-transport rates – and consequently ignition, flammability, fire characteristics, and flame-spread rates – vary considerably from those experienced in conventional, terrestrial fires. At partial gravity levels, the effects of buoyancy, convection, and diffusion can combine to produce unique combustion results. Thus, fire prevention, detection, and suppression practices for spacecraft and extraterrestrial habitats must be developed specifically to respond to the unique aspects of microgravity combustion.

To address these and other issues, a workshop entitled "Research for Space Exploration: Physical Sciences and Process Technologies," sponsored by the Microgravity Research Division of NASA was held in Cleveland in 1997. Broad research priorities for spacecraft fire safety developed in this workshop were as follows:

1. Research on electrical system diagnostics to provide an early, pre-incident warning to breakdowns, possibly resistivity or continuity checks.

2. Determination of flammability, flame spread, flame luminosity, limiting oxygen, and soot sizes under various atmospheres for thick materials and polymers at 1/3 g.
3. Determination of flame sizes, soot sizes, and flammability from thick materials with imposed heat flux under microgravity conditions.
4. Determination of combustion limits, ignitability, and flame luminosity of premixed methane and oxygen for propulsion and fire safety.
5. Research on fundamental behavior of various gaseous, liquid extinguishants, and solid-surface fires at 1/3 g and microgravity with modeling and experiment verification.

While many of these remain as relevant research areas, the missions for which fire safety research is required are evolving. Instead of developing knowledge of fire safety procedures and systems for the initial occupancy of the International Space Station, we are now concerned with maintaining, validating, and improving fire safety on the ISS throughout its lifetime while providing maximum flexibility in the types of experiments and operations that can be conducted. We must also look forward to the special fire safety requirements for travel to and habitation of the Moon and Mars. Research needs for these applications may include:

- Evaluation of fire initiation hazards arising from waste disposal, trash storage, laundry, household activities, and the storage of fuel gas and oxygen systems,
- Development of technology for the efficient detection systems required for long-duration missions in terms of rapid response, discrimination, false-alarm rejection, multiple-sensor logic, *etc*.,
- Identification and evaluation of new suppression agents and techniques required for long-range missions, Lunar or Martian habitation, and in-situ resource utilization (ISRU) extinguishment,
- Identification of fire safety issues in ISRU operations such as operations at high temperature and pressures, oxygen handling, propellant storage, and safety in welding and thermal operations.

Approach

To address these issues, researchers and specialists from academia, industry, national laboratories, and NASA who work in the various theme areas of fire safety such as applied combustion science and technology; environment control and life support; material flammability testing and fire prevention; spacecraft, habitat, and ISS design; and fire detection and suppression have been invited to this workshop. These participants will participate in one of three working groups that will focus on research needs in (1) fire prevention and material flammability, (2) smoke and fire detection, and (3) fire and post-fire response. The list of participants in each working group, their organization, and e-mail address is shown in Attachment 1. (An attendee list with complete contact information will be provided at the workshop.) The co-chairs for each working group are also shown in Attachment 1.

A schedule for the workshop including room assignments for all activities is shown in Attachment 2. The plenary session will open on Monday, June 25 at 8:00 a.m. with a brief presentation reviewing the spacecraft fire safety objectives in NASA's Bio-Astronautics Initiative and goals for the workshop. The other speakers in the plenary session will present various practical and operational fire safety concerns in current and future space missions, including practical aspects of material certification, operational concerns of fire safety related to manned space flight, current ISS fire protection systems, and anticipated processes for in-situ propellant production. A laptop PC computer, LCD projector, and overhead will be available for these plenary presentations, as well as for presentations in each of the three working groups.

Following the plenary session, three simultaneous discussion groups, each led by two co-moderators, will convene to begin discussions in their respective areas. The moderators will be responsible for facilitating the discussion on the theme areas and maintaining a summary of the deliberations. A more complete description of the working groups, their focus areas, and anticipated operation is given in Attachment 3. On Tuesday, June 26, the working groups will meet briefly in the morning to complete their discussions and review their conclusions. Following these sessions, all participants will convene for a closing session during which the moderators will present their recommendations and prioritizations for future research to the workshop participants.

The workshop will officially close at noon on Tuesday. After lunch, the working group co-leaders are requested to work on written documents to summarize the recommendations of their group. Any participants who are able to stay into the afternoon and assist in this effort may do so. Completion of these written summaries prior to leaving Cleveland will greatly accelerate the dissemination of the results of the workshop to the spacecraft fire

safety community. The workshop technical organizer will publish a compendium of these reports in the workshop proceedings.

The LaGuardia Room will be available during the workshop for informal discussions and breaks. Cell phones will be available during the workshop at the Workshop Registration Desk for use by the participants. If you ask for the cell phone number during registration and give it to your organization, you can receive incoming calls at the Registration Desk. The support personnel will notify you immediately if you receive a call during the workshop. Information and forms regarding travel reimbursement will be made available at the workshop.

If you have questions regarding the workshop, please contact the individuals listed below:

Technical Information Contact:	Gary A. Ruff (216) 433-5697 Gary.A.Ruff@grc.nasa.gov
Logistical Information Contact:	Christine Gorecki (216) 433-2851 Christine.R.Gorecki@grc.nasa.gov

ATTACHMENT 1

Fire Prevention and Material Flammability Working Group

Co-Moderators: James T'ien, Case Western Reserve University, Cleveland, OH
Dennis Griffin, Marshall Space Flight Center, Huntsville, AL

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22	Tucker, James	Applied Research Assoc, Wright-Patterson AFB	james.tucker@wpafb.af.mil
23	Wu, Ming-Shin	National Center for Microgravity Research	Ming-Shin.Wu@lerc.nasa.gov

ATTACHMENT 1

Smoke and Fire Detection Working Group

Co-Moderators: David L. Urban, NASA Glenn Research Center, Cleveland, OH
Thomas Cleary, National Inst of Standards and Technology, Gaithersburg, MD

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3	Hegde, Uday	National Center for Microgravity Research	Uday.G.Hegde@grc.nasa.gov
4	Hunter, Gary	NASA Glenn Research Center	gary.w.hunter@grc.nasa.gov
5	Lueck, Dale	NASA Kennedy Space Center	Dale.Lueck-1@ksc.nasa.gov
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ATTACHMENT 1

Fire and Post-Fire Response Working Group

Co-Moderators: Robert Friedman, NASA Glenn Research Center, Cleveland, OH
J. Michael Bennett, Wright-Patterson AFB, Dayton, OH

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ATTACHMENT 2

Workshop Schedule

Monday, June 25

Event	7:00 AM	8:00 AM	8:30 AM	9:00 AM	9:30 AM	10:00 AM	10:15 AM	10:45 AM
Plenary (Grand Ballroom)	Registration/ Continental Breakfast (Grand Ballroom)	**Welcome** Ruff, Ostrach	**Materials Testing and Certification** Griffin NASA MSFC	**Spacecraft Fire Safety: A Human Space Flight Program Perspective** Pedley NASA JSC	**ISS Fire Protection and the ECLSS System** Whitaker NASA JSC	Break (Grand Ballroom)	**In-Situ Propellant Manufacture and Storage** Lueck NASA KSC	**Charge to Working Groups** Ruff
	11:00 AM	12:00 PM	1:30 PM	3:30 PM	4:00 PM	6:00 PM	6:30 PM	
Fire Prevention and Material Flammability (O'Hare Room)	**Moderators: T'ien, Griffin** Presentations: Torero, Fernandez-Pello Olson	Lunch (Lambert Room)	**Working Session**	Break (Grand Ballroom)	**Working Session**	Cash Bar (Lambert Room)	Dinner (Lambert Room)	
Smoke and Fire Detection (Dulles Room)	**Moderators: Urban, Cleary** Presentations: Urban, Hunter, Young		**Working Session**		**Working Session**			
Fire and Post-Fire Response (Hartsfield Room)	**Moderators: Friedman, Bennett** Presentations: Ross, Takahashi, Abbud-Madrid		**Working Session**		**Working Session**			

ATTACHMENT 2

Workshop Schedule

Tuesday, June 26

<table>
<tr><th>Event</th><th>7:00 AM</th><th>8:00 AM</th><th>9:00 AM</th><th>9:45 AM</th><th>10:30 AM</th><th>10:45 AM</th><th>11:30 AM</th><th>11:45 AM</th></tr>
<tr><td>Plenary
(Grand Ballroom)</td><td rowspan="4">Continental Breakfast (Grand Ballroom)</td><td></td><td>Fire Prevention and Materials Summary</td><td>Smoke and Fire Detection Summary</td><td rowspan="4">Break (Grand Ballroom)</td><td>Fire and Post-Fire Summary</td><td>Closing
Ruff</td><td rowspan="4">Lunch/Completion of Written Summaries (Working Group Leaders)
(Lounge)</td></tr>
<tr><td>Fire Prevention and Material Flammability
(O'Hare Room)</td><td>Working Session Wrap-up</td><td colspan="3" rowspan="3"></td><td colspan="2" rowspan="3"></td></tr>
<tr><td>Smoke and Fire Detection
(Dulles Room)</td><td>Working Session Wrap-up</td></tr>
<tr><td>Fire and Post-Fire Response
(Hartsfield Room)</td><td>Working Session Wrap-up</td></tr>
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ATTACHMENT 3

Description of the Working Groups and Their Operation

Each working group will consist of 15 – 25 people with two co-moderators. The sessions will begin with short presentations of current research related to spacecraft fire safety to familiarize the working group participants with current activities. Each working group will have a laptop PC computer and LCD projector and overhead projector for these presentations. The working groups will then focus on research needs in their respective areas. In addition to the computer and LCD and overhead projectors, transparencies, a flip chart and markers will be available to document the deliberations of their groups. Support staff and printing capability will be extremely limited during the workshop. Working group moderators are recommended to use the computer and projector to document the discussion as it occurs to simplify the preparation of the summary presentations and written documents. Every attempt will be made to keep the proceedings electronic until after the workshop.

A brief description of the focus areas for the three working groups is as follows:

Fire Prevention and Material Flammability –fire prevention related to applications of microgravity and partial-gravity research on ignition sources, solid-surface combustion, innovative test methods, flammability of thick and composite materials, evaluation of payloads, acceptance standards, waivered component criteria, risk assessments, *etc.*

Smoke and Fire Detection – combustion models for optimum detector response, risk assessments for optimum placement of detectors, application of microgravity and partial-gravity research on soot and emissions, response time and sensitivity requirements, false-alarm rejection, gas sampling and innovative detectors, multi-sensor installations, automated and manual responses to alarms, *etc.*

Fire and Post-Fire Response – combustion and flow models for fire spread, gaseous and particle hazards from fires and suppression, crew response in emergencies, application of microgravity and partial-gravity research of flame suppression, Halon replacements (for the Shuttle), innovative and non-gaseous extinguishants, suppression of oxygen-fed and liquid fires, payload fire suppression, fire response for long-term transit and planetary habitat missions, post-fire cleanup, *etc.*

In each of these areas, participants will evaluate current technology and practices against the stated objectives of the workshop, i.e., to (1) identify research needed to ensure fire safety in future Shuttle and International Space Station (ISS) systems and payloads, (2) promote ISS fire safety through proposals for innovative designs, operations, and validation procedures, (3) identify areas of concern related to fire safety inherent to long-duration space missions in Earth orbit and beyond, and (4) anticipate research required to plan and design habitats for planetary exploration. Where deficiencies in current knowledge exist, the working groups should then identify and assess the technological advances required to eliminate these deficiencies. At the end of this workshop, the co-moderators of each working group will present a summary of the deliberations of their working group to all participants for discussion and comment. Facilities will be provided for the co-moderators to prepare these summary presentations Monday evening and Tuesday morning. After the closing session, the moderators will prepare a written summary of the discussions and findings of their working group before leaving Cleveland. The Workshop Technical Coordinator will combine these summaries into a NASA Conference Publication for distribution to the attendees and fire safety community promptly after the workshop.